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automatic locomotive signal system,
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Vladimir GAVRILYUK[1]
Dmitrij ASTRAHANTSEV[2]

THE COMPUTER MODEL OF AUTOMATIC LOCOMOTIVE SIGNALS SYSTEM

In this work the computer model for investigation of frequency automatic locomotive signalization was proposed. The investigation of ALS current distribution for different parameters of data transfer channel was carried out.

KOMPUTEROWY MODEL AUTOMATYCZNEJ SYGNALIZACJI NA LOKOMOTYWIE

W pracy został przedstawiony komputerowy model badania częstotliwościowej automatycznej sygnalizacji pociągu. Zaproponowano badanie rozpływu prądu (odbiór sygnału) w urządzeniach sygnalizacji na lokomotywach, ze względu na różne parametry kanału przenoszącego dane.

1. INTRODUCTION

Traffic safety of trains is defined by reliability and completeness of transfer of the information about a condition of the rail lines ahead on the locomotive. According to normative documents on the organizations of movement of high-speed passenger trains, movement with a speed more than 160 km/h should be carried out on signals of multiple-valued automatic locomotive signal system (ALS). A railway of Ukraine have three-value numerical code ALS of continuous type, which alarm indications of traffic lights are transferred in a locomotive cabin by next codes: (***red-yellow, yellow, green***).

However, it is not enough three code signals for transfer all of the information. In case of four-unit, ALSS have before a traffic light with a green signal, and also before a traffic light with simultaneously burning yellow and green signal on the locomotive transfer an

[1] Department of Automatic and Telecommunications, Dnepropetrovsk National University of Railway Transport, Lazaryana 2, 49010 Dnepropetrovks, Ukraine, E-mail: gvi_dp@mail.ru
[2] Department of Automatic and Telecommunications, Dnepropetrovsk National University of Railway Transport, Lazaryana 2, 49010 Dnepropetrovks, Ukraine, E-mail: gardemarin@gmail.com

identical code such as ***green***. Besides at speeds more than 140 km/h are observed some failures off ALS signal transfer.

For sites with high-speed movement of trains in Russia the system multiple-valued frequency automatic locomotive signal system [1] is developed. The frequency automatic locomotive signal system with automatic speed control (ALS-ASC) is applied to regulation movement of trains in underground.

In the countries of the European community with the purpose of replacement of polytypic devices of the locomotive signal system the control system of movement of trains ETCS (European Train Control System) is developed. ETCS is a part of the European control system of transportation process on railway transportation ERTMS (European Railway Traffic Management System). In ETCS system some levels for the lines differing by congestion movement of trains are stipulated. Transfer of the information on the locomotive is carried out on continuous and dot channels.

The refusal of the rail circuits which are carrying out functions of rail line gauge of freely and integrity of a rail way, and also the continuous channel of transfer of the information is not planned by Ukrainian Railway. It does not contradict the concept of introduction to the European system ETCS according to which it is stipulated at the first stage to carry out management of movement of trains on the basis of existing national equipment of railway automatics.. However, low information ability of ALS system and limitation of functionalities cause a need in development of reliable system of transfer of the multiple-valued information on the locomotive, based on modern computer and network technologies.

2. THE PURPOSE OF THE WORK

The purpose of the work is development of mathematical model and building the computer application for research of the data link frequency automatics locomotive signalization system. The model describes centralized accommodation of the equipment and non-junction rail circuits. Then, a rational method of data coding of the locomotive signal system at physical and channel levels, based on this research, will be choused.

3. MATHEMATHICAL MODEL

The electric circuit of the channel of signaling of the automatic locomotive signal system on the locomotive is resulted on Fig.1.

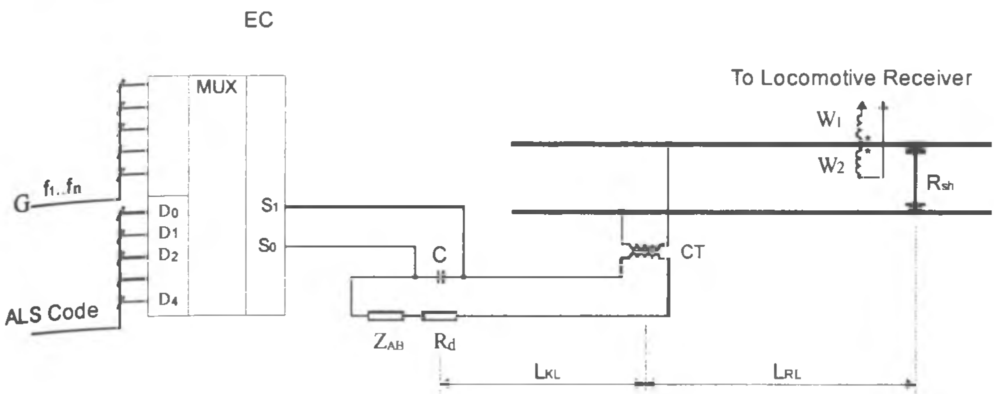

Fig.1. The Electric circuit of the ALS channel

Coding of signals frequency at a physical level is carried out by a set from N the fixed frequencies (on number of bits of the transmitted information) which are formed by the generator (G) of the group of signals. Values of bits of the transmitted information (D_N.. D_0) are formed depending on trains condition by the device of regulation, are supplemented at a channel level (Data Link Layer) with service bits and are grouped in the frames. From an output of the analog multiplexer (MUX) the generated signal as a combination n of frequencies from N possible is transferred in a cable line to signal points (in figure one signal point is shown) on which through ST transformer it is transferred in a rail line. From a rail line the signal on an inductive channel through coils W_1, W_2 is transferred to the locomotive.

The equivalent circuit of the channel of transfer frequency ALS system is resulted on Fig.2.

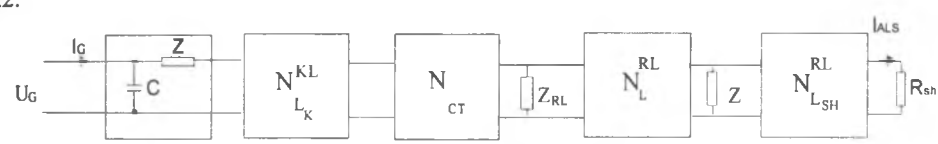

Fig.2. The Equivalent circuit of the channel of transfer frequency ALS system

In an equivalent circuit elements $Z = Z_{AB} + R_d$ also C correspond{meet} to the elements resulted on the electric circuit; $N^{KL}{}_{L_K}$ the two-port network corresponding to a cable line in length L_K, $Z_{VH\ RL}$ - entrance resistance of an adjacent rail line, $N^{RL}{}_{L}$ - the two-port network corresponding to a rail line in length L, $Z_{VH\ ST}$ - entrance resistance of the equipment connected to a rail line on the following alarm point, $N^{RL}{}_{L_{SH}}$ - the two-port network corresponding to a rail line of a zone of additional shunting in length L_{SH}, $R_{SH\ N}$ - resistance of the normative shunt (an equal 0,6 Ohm) $U_G(f_i)$, $I_G(f_i)$ - accordingly, a voltage and a current of the generator frequency f_i on input $U_A(f_i)$, $I_A(f_i)$ - a voltage a current frequency f_i on the normative shunt. It is obvious, that $U_A = R_{SH\ N} I_A$.

Currents and voltage on generating railway circuit and on locomotive's shunt are connected by the known equations for the two-port network [6]

$$\begin{aligned} U_G &= A_o U_{SH} + B_o I_{SH} \\ I_G &= C_o U_{SH} + D_o I_{SH} \end{aligned}, \tag{1}$$

Where A_0, B_0, C_0, D_o - coefficients of two-port networks. The matrix of these factors is defined{determined} as product of matrixes of factors of all two-port networks which are included in the equivalent circuit (Fig.2) in view of the two-poles included between them. Factors of two-port networks of a rail and cable line are under formulas for a line with the distributed parameters through its secondary parameters under formulas [6]

$$A = D = ch(\gamma L), \tag{2}$$

$$B = Z_c sh(\gamma L), \tag{3}$$

$$C = \frac{sh(\gamma L)}{Z_c}, \tag{4}$$

Where γ - a constant of distribution, Z_c - wave resistance, L - length of a line. Secondary parameters of a line are defined as follows [6]

$$\gamma = \sqrt{Z/Z_{iz}}, \tag{5}$$

$$Z_c = \sqrt{Z_{IZ}}, \tag{6}$$

Where Z, Z_{us} - is full resistance of conductors of a line and isolation between them.

At a presence of a full resistance of a rail line used the formula [5-6]

$$Z = 2R_n + j\omega L_p, \tag{7}$$

Where R_n - active resistance of a rail line of 1 km, L_p - inductance of a rail line. Using for their presence known expressions in which frequency dependences of active $R_n^*(\omega)$ and complex resistance $X_n^*(\omega)$ of a rail string on an alternating current are approximated which are taking into account as non-uniformity of distribution of a current on section of a rail by the L.Nejnman's formulas, and Deadband effect in steel [5-6]

$$\begin{aligned} R_n^*(\omega) &= \frac{l}{u}\sqrt{\mu_e \rho \omega} \\ X_n^*(\omega) &= 0.6\frac{l}{u}\sqrt{\mu_e \rho \omega} \end{aligned}, \tag{8}$$

Where l - length of a conductor, u - perimeter of his{its} cross-section section, ρ - specific resistance of rail steel, $\omega = 2\pi f$ - angular frequency, μ_e - the magnetic permeability of rail steel determined on a curve of magnetization. Comparison of the values designed on these formulas full resistance of a rail line with the values received in the experimental way, has shown good enough concurrence of results.

The entrance signal submitted from the generator in the channel of signaling ALS system represented as the sum n of harmonious signals from N possible with the frequencies f_i $(i = 1..N)$, transmitted in a line during an interval of time t_u then for the period of a pause t_n submission of a signal in a line stopped. Analytically entrance signal can be presented as

$$u_G(t) = \frac{1}{2}\sum_{i=1}^{N} D_i \dot{U}_i \exp(j\omega_i t), \tag{9}$$

$$i_G(t) = \frac{1}{2}\sum_{i=1}^{N} D_i \dot{I}_i \exp(j\omega_i t), \tag{10}$$

For intervals of time $kT \le t \le kT + t_u$ ($n = 0..\infty$) , i.e. for intervals during which in the channel signal ALS system and $u_G(t) = 0$, $i_G(t) = 0$ during a pause t_n moves. Values D_i correspond a bit of a code and accepts values 0 or 1.

4. RESULTS OF MODELING

Results of the analysis of transfer of frequency signals of the ALS system on an inductive channel from a rail line in locomotive coils are described in [2, 3]. In the given work the data link up to locomotive coils is investigated. Calculations were carried out for the greatest possible distance of the locomotive from generating end of railway circuit (on border of a zone of additional shunting) under various conditions, including the most adverse for performance of ALS system mode. The analytical decision of such problem is impossible. For the numerical decision on the basis of the resulted mathematical description the computer program in language $C\#$ has been developed. An entrance signal (9, 10) decomposed by fourier transform, were limited in conformity from the set accuracy to necessary quantity of harmonious components. Then for each harmonious component found ALS current in a rail line. The received currents summarized and found resulting current ALS system. Examples of appearance of a window of the program for two code combinations of signals ALS system are resulted on Fig.3. In the top windows of the program time dependence of a voltage acting from generators in ALS channel, and on the right - spectral structure of a signal at the left is shown. In the bottom windows time dependence and the spectrogram of current ALS are resulted, accordingly. Apparently from the resulted data, the spectral structure of a signal changes at passage on the channel. Change is caused by nonlinearity amplitude and faze characteristics of the channel.

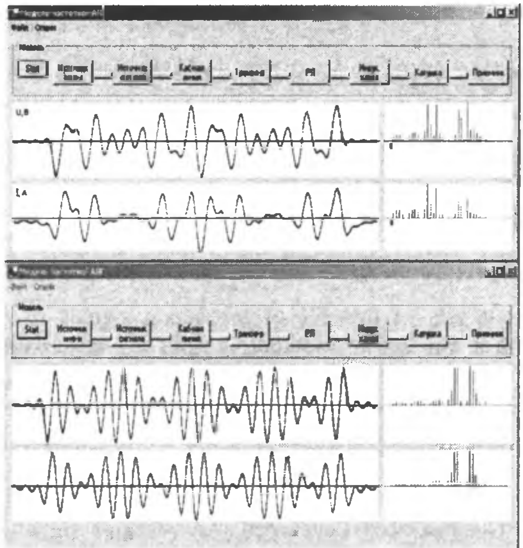

Fig.3. Appearance of a window of the program of modeling frequency ALS system for two code combinations of signals

On Fig.4 are resulted dependence of a frequency ALS system current I_A from distance from having railway circuit end up to the locomotive L for five frequencies (125, 175, 225, 275, 325 Hz) at length of a cable of 10 km. On Fig.5 dependence $I_A(L)$ for frequencies of 125 and 325 Hz at two lengths of a cable (5 and 10 km).

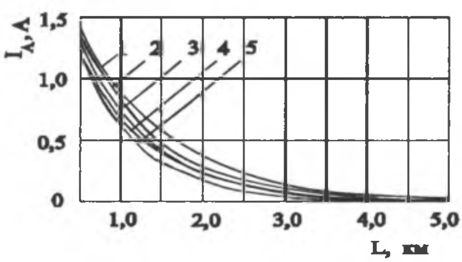

Fig.4. Dependence of a frequency ALS system current I_A from distance

Apparently from figure, the length of a cable does not render significant influence on character of change of ALS system current in a rail line. Presence in the circuit of the additional resistor R_d compensating distinctions in lengths of a cable. On Fig.6 dependence $I_A(L)$ for two frequencies (125 and 325 Hz) is resulted at two values of resistance of isolation of a ballast (1 and 0,5 Ohms / km). Apparently from figure, reduction of resistance of isolation of a ballast from 1 up to 0,5 Ohms / km leads to significant reduction of ALS system current in a rail line.

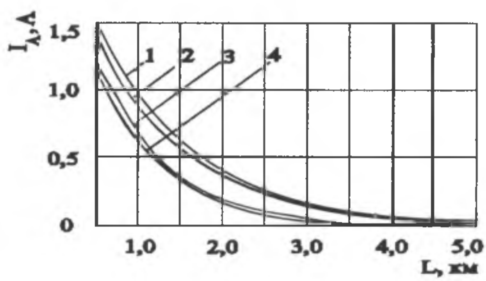

Fig. 5. Dependence of a frequency ALS system current I_A from distance up to the locomotive L at frequencies (Hz): 125 (1, 2), 325 (3, 4) at length of a cable: (km) 5 (1, 3) and 10 (2, 4)

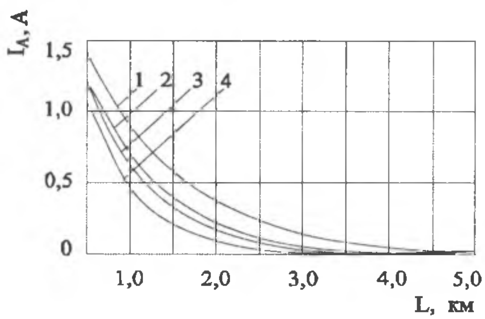

Fig. 6. Dependence of a frequency ALS system current I_A from distance up to the locomotive L at frequencies (Hz): 125 (1, 2), 325 (3, 4) at resistance of isolation of a ballast: (Ohm / km) 1 (1, 3) and 0,5 (2, 4)

In the developed computer model the opportunity of research of influence of noise in a line on transfer of ALS system codes is stipulated. At modeling there is a constant calculation of mistakes of transfer of information of the signals given by comparison channel information and information, which has been received on the locomotive. It allows to lead a rational choice of code signals at a physical and channel level by criterion of minimization of amount of incorrectly accepted frames of the information.

5. CONCLUSION

In work the mathematical model and the computer program application for research of the data link is developed.

The model is developed at the centralized arrangement of the equipment and non-junction rail circuits.

Research distribution of an ALS current frequency is lead at various parameters of the data link.

BIBLIOGRAPHY

[1] ZORIN V.I., SHUHINA E.E., TITOV P.V., New generation of microprocessor locomotive systems of a safety of movement of trains, Railways of the world – 2002, № 7. - P. 19-25.
[2] GAVRILJUK V.I., TOVCHIGRECHKO Y.G., Modeling of a change of a current ALS-ASC in voice-frequency rail circuits of underground at movement of a train. The information and managing systems on the railway transport – 2003, №4. – P. 27-31.
[3] ASTRAHANTSEV D., GAVRILJUK V. Theoretical and experimental researches of voice-frequency signal current transfer in rail lines // Transport System Telematics: 4th International Conference. – 2004, – P. 21-26.
[4] DMITRIEV V.S., MININ V.A. The perfection of systems of automatic lock-out. - Moscow: Transport, 1987,- P. 143.
[5] ARKATOV V.A., KRAVTSOV J.A., The Circuit of a Railway. The analysis of work and maintenance service. - Moscow, Transport, 1990,- P. 295.

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